

RX J1856.5-3754: A strange star with solid quark surface?

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Abstract. Within the realms of the possibility of solid quark matter, we fitted the 500ks Chandra LETG/HRC data for RX J1856.5-3754 with a phenomenological spectral model, and found that electric conductivity of quark matter on the stellar surface is about $> 1.2 \times 10^{18} \text{ s}^{-1}$.

1. Introduction

Neutron stars provide a unique opportunity for researchers who are interested in obtaining experimental information of matter in extremely high density, especially of the density-dominated quark matter if a special kind of neutron stars, the so called strange stars, exist. However, how to identify strange stars is still a matter of great challenges, and becomes a hot topic in astrophysics.

The featureless spectra of isolated “neutron” stars may be evidence for *bare* strange stars (Xu 2002), but a definitive conclusion on the nature of the compact objects cannot be reached until theoretically calculated spectra of the bare quark surface are known. However, due to the strong nonlinearity of quantum chromodynamics, it is almost impossible to present a definitive and accurate calculation of the density-dominated quark-gluon plasma from the first principles. Nevertheless, it is suggested that cold quark matter with extremely high baryon density could be in a solid state (Xu 2003). We then try to fit the thermal X-ray spectrum of the brightest isolated neutron star RX J1856.5-3754 in this regime.

2. Fitting the data and results

In solid quark matter, the interactions between electrons or between electrons and photons, could be responsible to the thermal photon radiation, which could be analogous to the radiation of metals to some extent. We will fit the thermal spectrum obtained from Chandra LETG/HRC observations of RX J1856.5-3754 (total exposure time about 500ks) with the metal emissivity (Born & Wolf 1980) $\psi(\nu, T) = \alpha(\nu)B(\nu, T)$, with $\alpha(\nu) = 1 - (2\sigma/\nu + 1 - 2\sqrt{\sigma/\nu})/(2\sigma/\nu + 1 + 2\sqrt{\sigma/\nu})$ and $B(\nu, T)$ the blackbody emissivity.

Chandra LETG/HRC has performed five observations of RX J1856.5-3754 in March 2000 and October 2001, with a total exposure time ~ 500 ks. Starting from the event2 files and following the CIAO threads (<http://cxc.harvard.edu/ciao/threads/gspec.html>), we extracted the spectra and generated the corresponding effective area files for each observation, and combined them for fitting. The plus order and minus order spectra were combined separately, and a joint fitting was performed. To avoid the artificial features across the gaps between CCDs, we ignored 0.18–0.21 keV in the plus order and 0.21–0.26 keV in the mi-

nus order. The spectra were grouped so that each channel has at least 300 counts. We fit the spectrum with both a pure black-body model and a metal thermal model, both with interstellar absorption. The fitting result is shown in Table 1.

Model	nH 10^{20}cm^{-2}	kT_{bb}^{∞} eV	R_{bb}^{∞} km ($d/120\text{pc}$)	σ 10^{18}s^{-1}	χ^2/dof
(a)	0.86 ± 0.03	64.1 ± 0.5	4.1 ± 0.1	-	830/970
(b)	0.72 ± 0.03	59.5 ± 0.5	$>(7.4, 5.9, 4.9)$	$>(1.24, 0.38, 0.14)$	809/969

Table 1. Fitting result: (a) absorbed blackbody, (b) absorbed metal thermal spectrum. In (b), the lower limits of σ and R_{bb}^{∞} are in 1σ , 2σ and 3σ confidence levels, respectively.

The metal model provides a slightly better fit to the data. Since σ and R_{bb}^{∞} are coupled together, we can only determine lower limits for the value of σ or R_{bb}^{∞} from the fitting. The parameters for the absorbed black-body model are a little different from those obtained from the same observations by Burwitz et al (2003). A possible reason is that we used different binning of the spectra. However, the lower limit of neither R_{bb}^{∞} nor σ is sensitive to the binning.

3. Discussions

Within the realms of solid quark surface, we have fitted the 500ks Chandra LETG/HRC data for the brightest isolated neutron star RX J1856.5-3754 with a phenomenological spectral model. However, the UV-optical excess (e.g., Burwitz et al. 2003) has not been included in the fitting. Actually the origin of this excess is still academically controversial. We suggest that the emission is not from the stellar surface. During a propeller phase with low accretion from interstellar medium, a quasistatic atmosphere (envelop) may form around the magnetosphere of RX J1856.5-3754. The dissipation of stellar rotation energy may heat the envelop, which could be responsible for the UV-optical emission. Detailed investigation on this issue is necessary if one conceives a study to know the environmental status of isolated neutron stars.

If the electrons near the Fermi surface are responsible for the conduction, the fitted σ implies the relaxation time $\tau > \sim 8 \times 10^{-21}$ s, while the $e-e$ collision timescale $\tau \sim 2.3 \times 10^{-16}$ s. The conductivity fitted could be reasonable.

Strong magnetic fields and/or fast rotation may help a neutron star to reproduce a featureless spectrum. However, the thermal radiation mechanism is very different from ours, which results in a possible test in the future.

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References

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